DECLARATION

I, Masakazu ITO, a citizen of Japan, c/o Miyoshi & Miyoshi of Toranomon Kotohira Tower, 1-2-8 Toranomon, Minato-ku, Tokyo 105-0001, Japan, do hereby solemnly and sincerely declare:

That I am well acquainted with the Japanese language and English language; and

That the attached is a true and faithful translation made by me of the Japanese document, namely Japanese Patent Application No. 2002-254858 to the best of my knowledge and belief.

This 27th day of September, 2005

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Method for Manufacturing a Semiconductor Substrate Provided with a Through-Hole Electrode and Method for Manufacturing a Semiconductor Device Provided with a Through-Hole Electrode
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Method for Manufacturing a Semiconductor Substrate Provided with a Through-Hole Electrode and Method for Manufacturing a Semiconductor Device Provided with a Through-Hole Electrode

[Claims]

[Claim 1] A method for manufacturing a semiconductor substrate provided with a Through-hole electrode that connects by wring, the principal sides of a semiconductor substrate, the manufacturing method comprising:

a first insulating layer formation step for forming a first insulating layer on at least one of the principal sides of a semiconductor substrate;

a small opening formation step for forming a small opening through said semiconductor substrate from the other principal side thereof reaching through to said first insulating layer on said one of the principal sides ;

a second insulating layer formation step for forming a second insulating layer on the inside surface of said small opening;

a thin film formation step for forming a thin metal film on said first insulating layer at least at the end of said small opening

a insulating layer removal step removing said first insulating layer at that end of said small opening; and

a conductive material filling step for filling a conductive material into said small opening in order to form a through-hole electrode .

[Claim 2] The method for manufacturing a semiconductor substrate provided with a through-hole electrode according to claim 1 wherein said small opening is formed by the deep-reactive ion etching method.

[Claim 3] The methods for manufacturing a semiconductor substrate provided with a through-hole electrode according to claim 1 and claim 2 wherein said thin metal film is formed by stacking two or more layers of different kinds of metals.

[Claim 4] A method for manufacturing a semiconductor device provided with a through-hole electrode that connects by wiring, the principal sides of a semiconductor substrate on which a device is formed, this manufacturing method comprising:

a first insulating layer formation step for forming a first insulating layer on at least one principal side of a semiconductor substrate on which a device is formed;

a thin film formation step for forming a thin metal film on said insulating layer ;

a small opening formation step for forming a small opening through said semiconductor substrate from the other principal side thereof reaching through to said insulating layer directly under said thin conductive film;

a second insulating layer formation step for forming a second insulating layer on the inside surface of said small opening and on the other principal side of said semiconductor substrate;

a insulating layer removal step for removing said insulating layer at the end of said small opening; and

a conductive material filling step for filling a conductive material into said small opening in order to form a through-hole electrode.

[Claim 5] The method for manufacturing a semiconductor device provided with a through-hole electrode according to claim 4 wherein said small opening is formed by the deep-reactive ion etching method.

[Claim 6] The methods for manufacturing a semiconductor device provided with a through-hole electrode according to claim 4 and claim 5 wherein said thin metal film is formed by stacking two or more layers of different kinds of metals.

[DETAILED DESCRIPTION OF THE INVENTION]
[0001]
[Field of the Invention]
The present invention relates to a method for manufacturing a semiconductor device provided with a through-hole electrode and a method for manufacturing a semiconductor substrate provided with a through-hole electrode used for wiring of an electronic device or an optical device and the like, or for a wiring layer for stacking devices and wiring them.

[0002]
[Description of Prior Art]
Semiconductor substrates provided with a through-hole electrode are used for wiring a variety of devices such as electronic devices and optical devices and the like and for a wiring layer for stacking devices and wiring them. FIG. 7 provides a schematic cross-sectional drawing showing an example of the structure of a semiconductor substrate provided with a through-hole electrode. This semiconductor substrate provided with a through-hole electrode is composed of a semiconductor substrate 1 made of a silicon substrate and the like, an insulating layer 2 formed on the surface of the semiconductor substrate 1 and on

the side wall of a small hole 4 formed through the semiconductor substrate 1 and a through-hole electrode 3 made of a conductive material such as metal with which the small hole 4 is filled.

[0003]
The manufacturing method of such a semiconductor substrate provided with a through-hole electrode will now be explained with reference to FIG. 8.

First of all, as illustrated in FIG. 8 (a), a step for forming the small hole is performed, in which the small hole 4 is formed through the semiconductor substrate 1. The small hole 4 can be formed by DRIE (deep-reactive ion etching) as typified by ICP-RIE (inductively coupled plasma-reactive ion etching), anisotropic etching making use of a potassium hydroxide solution and the like, machining with a microdrill, photon assisted electrolytic grinding method and so forth.

Then, as illustrated in FIG. 8 (b), a step for forming an insulating layer is performed, to form the insulating layer 2 on the surface of the semiconductor substrate 1 and the side wall of the small hole4.

Next, as illustrated in FIG. 8 (c) the small hole 4 is filled with a conductive material such as a metal, by a molten metal suction method, a sputtering method, plating method or screen printing method and the like to form the through-hole electrode 3, thereby obtaining a semiconductor substrate provided with a through-hole electrode.

[0004]
The semiconductor substrate provided with a through-hole electrode manufactured in this matter can be used as a substrate for manufacturing a variety of devices, or as shown in FIG. 9, can be used as an interposer for stacking other devices and wiring them by forming a wiring 5 of conductive material such as metal and the like.

[0005]
[Problems to Be Solved by the Invention]
As described above, in accordance with the conventional manufacturing method of a semiconductor substrate provided with a through-hole electrode, various types of devices and wiring patterns are fabricated after forming a through-hole electrode in a semiconductor substrate. Because of this, there are restrictions on the processing temperatures that can be used depending on the properties of the conductive material forming the through-hole electrode, which limits the selection of devices and wiring patterns that can be constructed.

For example, while sintering is performed at about 400° C when forming a wiring pattern made of aluminum, if the through-hole electrode is made of a eutectic metal such as gold and tin (Au-Sn) or a conductive paste, the metal may become

molten due to the thermal treatment or the properties of the conductive paste may be changed.

[0006]
Further, when fabricating electronic devices on a semiconductor substrate provided with a through-hole electrode as described above, the following problems arise in the fabrication process.

In order to avoid heavy metal contamination, the bringing of metals other than a conventional wiring metal such as aluminum into a clean room where electronic devices are fabricated should be strenuously avoided. The fabrication processes employed in forming devices or wiring on a semiconductor substrate provided with a through-hole electrode uses various equipment such as a deposition system or a pattern aligner and therefore is not desirable from the viewpoint of preventing contamination. If a semiconductor substrate provided with a through-hole electrode or a device fabricated thereon is contaminated the characteristics of not only the semiconductor substrate itself, but also of other electronic devices having no through-hole electrode may also suffer deterioration due to cross-contamination occurring via such equipment. Accordingly, when using a through-hole electrode in an electronic device, the processes of forming the through-hole electrode should be performed as much as possible at the final stages of the manufacturing process.

[0007]
Moreover, there are usually irregularities of several micrometers on the surface of a through-hole electrode and these may have an effect on the manufacturing process depending on the device being produced. For example, when a resist is coated on a semiconductor substrate provided with a through-hole electrode using a spin coater, achieving a uniform coating in the vicinity of such irregularities when present, is difficult.

[0008]
With the foregoing in view, the present invention was made; and the object thereof is to provide a manufacturing method of a semiconductor substrate provided with a through-hole electrode and a manufacturing method of a semiconductor device having a through-hole electrode wherein the through-hole electrode can be formed efficiently in a semiconductor substrate on which a device or wiring pattern has already been formed.

[0009]
[Means for Solving the Problem]

The present invention provides a method for manufacturing a semiconductor substrate provided with a through-hole electrode, that connects by wiring, the principal sides of a semiconductor substrate, the manufacturing method comprising:

a first insulating layer formation step for forming a first insulating layer on at least one of the principal sides of the semiconductor substrate,

a small opening formation step for forming a small opening through the semiconductor substrate from the other principal side thereof reaching through to the first insulating layer on said one of the principal sides,

a second insulating layer formation step for forming a second insulating layer on the inside surface of the small opening,

a thin film formation step for forming a thin conductive film on the first insulating layer at least the end of the small opening

,

an insulating layer removal step for removing the first insulating layer at that end of the small opening, and

a conductive material filling step for filling a conductive material into the small opening in order to form a through-hole electrode.

The present invention further provides a method for manufacturing a semiconductor device provided with a through-hole electrode, that connects by wiring, the principal sides of a semiconductor substrate on which a device is formed, this manufacturing method comprising:

a first insulating layer formation step for forming a first insulating layer on at least one principal side of the semiconductor substrate on which a device is formed,

a thin film formation step for forming a thin conductive film on the insulating layer,

a small opening formation step for forming a small opening through the semiconductor substrate from the other principal side thereof reaching through to the insulating layer directly under the conductive thin film,

a second insulating layer formation step for forming a second insulating layer on the inside surface of the small opening and on the other principal side of the semiconductor substrate,

an insulating layer removal step for removing the first insulating layer at the end of the small opening, and

a conductive material filling step for filling a conductive material into the small opening in order to form a through-hole electrode.

It is preferable for the small opening to be formed by the deep-reactive ion etching method.

It is further preferable for the thin metal film to be formed by stacking two or more layers of different kinds of metal.

[0010]
[PREFERRED EMBODIMENTS OF THE INVENTION]

The present invention will now be described.

An embodiment of the method for manufacturing a semiconductor substrate provided with a through-hole electrode according to the present invention will now be described with reference to FIG. 1 and FIG. 2.

For this embodiment a method of manufacturing a semiconductor substrate provided with a through-hole electrode to be used as an interposer for stacking and wiring an electronic device will be described.

FIG. 1 depicts this manufacturing method for a semiconductor substrate provided with a through-hole electrode according to this embodiment in the order of the various processing steps thereof; it is the cross-section view of the semiconductor substrate cut away along the longitudinal direction of the through-hole electrode. FIG. 2 is a plan view of the semiconductor substrate provided with a through-hole electrode viewed from above.

[0011]
As shown in FIG. 1 (a), in this semiconductor substrate provided with a through-hole electrode, a semiconductor substrate 11 made of a silicon substrate having a thickness of 300 μm or thereabout has a first silicon oxide film 12, providing an insulating layer, having a thickness of 1 μm formed on both principal sides thereof (first insulating layer formation step). In this embodiment this first silicon oxide film 12 is formed for example, by thermal oxidation at 1000° C for four hours.

The first silicon oxide film 12 can also be formed by a plasma CVD technique, a sputtering technique or the like instead of thermal oxidation, in accordance with the film thickness or the desired application thereof.

[0012]
In this embodiment a silicon substrate is used as the semiconductor substrate 11 and thus it is possible to easily form the first silicon oxide film 12 of the insulating layer by the process of thermal oxidation or the like. Further, if a silicon substrate is used a small hole as described subsequently can be formed with precision in the surface of the semiconductor substrate 11 by deep-reactive ion etching (DRIE).

Further, forming the first silicon oxide film 12 provides insulation between a thin metal film formed at a subsequent step and the semiconductor substrate 11.

Thus, by patterning this thin metal film in accordance with a desired profile, the thin metal film can be used as a wiring pattern between the through-hole electrode and an electronic device disposed on the semiconductor substrate 11.

Again, when the semiconductor substrate provided with a through-hole electrode is used as an interposer for stacking an electronic device, this thin metal film can be used as a wiring layer.

Moreover, as the first silicon oxide film 12 is used as an insulating layer, when forming the small hole using DRIE, the first silicon oxide film 12 functions as an etching stop layer, thus the small hole can be formed uniformly in the surface of the semiconductor substrate 11. Also, it is possible to remove just the first silicon oxide film 12 only by selecting an appropriate etching gas. In this case, as described subsequently, the thin metal film can serve as an etching stop layer enabling the formation of the desired small hole just below the metal film in a consecutive series of manufacturing steps.

[0013]
Next, as illustrated in FIG. 1 (b) the first silicon oxide film 12 on one of the principal sides, surface A, is partially removed at a location where the through-hole electrode is to be formed.

Thereafter, as illustrated in FIG. 1 (c), a small hole 13 is formed through the semiconductor substrate 11 from the principal surface A on one side through to the first silicon oxide film 12 formed on the other principal surface using a deep-reactive ion etching method (in the small hole formation step). Here, the deep-reactive ion etching method involves using sulfur hexafluoride (SF6) or the like, and is performed by high-density plasma etching and alternate formation of passivation films on the side wall of the small hole 13 (the Bosch process) as deep etching is performed on the semiconductor substrate 11.

The form of the cross-section on the plane perpendicular to the depthwise direction of the small hole 13 may have any profile such as a circle, an ellipse, a triangle, a square, a rectangle and so forth, the size thereof being determined in accordance with the size and conductivity (resistance) of the desired semiconductor substrate provided with a through-hole electrode.

[0014]
Using the DRIE technique it is possible to easily perform microscopic machining of the small hole 13, moreover, by using an appropriately selected semiconductor substrate and etching gas, the small hole 13 can be formed and the first silicon oxide film 12 just below the thin metal film can be removed in consecutive processes as described subsequently, thereby enabling the desired small hole 13 to be formed efficiently.

[0015]

Next, as illustrated in FIG. 1 (d), a second silicon oxide film 14 having a thickness of 1 μm or thereabouts is formed on the inside surfaces of the small hole 13 (second insulating layer formation step). In this embodiment, the second silicon oxide film 14 is formed by for example, by thermal oxidation at 1000° C for four hours.

The second silicon oxide film 14 can also be formed by a plasma CVD technique, a sputtering technique or the like instead of thermal oxidation, in accordance with the film thickness or the desired application thereof.

Forming the second insulating layer on the inside surfaces of the small hole 13 in this way enables the semiconductor substrate 11 to be insulated from a conductive material that is filled into the small hole 13 at a later step.

[0016]
Next, as illustrated in FIG. 1 (e) a first thin metal film 15 and a second thin metal film 16 made of different materials are formed on the first silicon oxide film 12 at least in a location just above the small hole 13 (thin film formation step). In this embodiment, the first thin metal film 15 and the second thin metal film 16 are formed for example by a sputtering technique.

If necessary, it is possible, by patterning these thin metal films by an appropriate method, to form an electrode pad 22 on the through-hole electrode part 21 as shown in FIG. 2 (a), another electrode pad 23 on the substrate 20 as shown in FIG. 2 (b) and wiring 24 connecting these. In this embodiment, for example an aluminum silicon (Al-SI) thin film is formed as the first thin metal film 15 while an aluminum (Al) thin film is formed as the second thin metal film 16.

According to this embodiment an aluminum silicon film is used for the first thin metal film 15 and an aluminum thin film is used for the second thin metal film 16, however this is not restrictive and other metallic materials may be used. For example, in order to increase the adhesiveness of the first thin metal film 15 to the through-hole electrode 17 the first thin metal film 15 can be formed by selecting from among gold, platinum, titanium, silver, copper, bismuth, tin, nickel, chromium, and zinc and other suitable metals and alloys thereof or by combining those material, depending upon the type of conductive material with which the small hole 13 is filled.

Further, in order to improve the adhesiveness of the second thin metal film 16 to a solder bump or wiring pattern (wiring) disposed on another semiconductor substrate, the second thin metal film 16 can be formed by selecting a metallic material from among gold, platinum, titanium, silver, copper, bismuth, tin, nickel, chromium and zinc and alloys thereof or by combining those material, depending upon the type of solder bump or wiring pattern.

Moreover, while the thin metal film formed on the semiconductor substrate 11 is a two layered arrangement comprising a first thin metal film 15 and a second thin metal film 16, the present invention is not limited by this description and it is possible to form the thin metal film in a multiple layered structure made of three or more layers of different metal.

[0017]
By forming the thin metal film on the semiconductor substrate 11 in a multiple layered structure made of two or more layers of different metals, it is possible to improve the adhesiveness of the thin metal film to the conductive material filled inside the small hole 13 and therefore possible to achieve reliable electrical connection between the through-hole electrode 17 and the thin metal film (in this case, the first thin metal film 15 and the second thin metal film 16).

[0018]
Next, as illustrated in FIG. 1 (f), the first silicon oxide film 12 is removed by an etching process, only at the end part of the side of the small hole 13 at which the first thin metal film 15 and second thin metal film 16 are formed, exposing the first thin metal film 15 to the inside of the small hole 13 (insulating layer removal step). In this embodiment the first silicon oxide film 12 is etched by dry etching method of an RIE (reactive ion etching) technique using carbon tetrafluoride (CF subscript 4) as an etching gas.

[0019]
Next, as illustrated in FIG. 1 (g), a conductive material is filled into the small hole 13 by a molten metal section method or a printing method to form the through-hole electrode 17 thereby constructing a semiconductor substrate provided with a through-hole electrode.

This process of filling a conductive material into the small hole 13 at the conductive material filling step electrically connects the first thin metal film 15 and second thin metal film 16 to the through-hole electrode 17.

[0020]
Here, the molten metal suction method involves filling a molten metal into the small hole by dipping the semiconductor substrate in a molten metal bath in a reduced pressure environment such as a vacuum chamber or the like and then increasing the pressure (for example by decreasing the degree of vacuum or increasing to the atmospheric pressure). In this molten metal suction method, as the conductive material, for example a eutectic composition of 80% by weight of gold (Au) and 20% by weight of tin (Sn) may be used. If this molten metal suction method is used to fill the small hole 13 with a conductive material, even a microscopically small hole 13 can be filled effectively. Further, as the small hole 13 can be completely filled with the conductive material through to the end part thereof, the first thin metal film 15 and the second thin metal film 16 are

electrically connected to the through-hole electrode 17 formed of this conductive material such that the through-hole electrode 17 functions as an electrode.

Although the small hole 13 may be filled with the conductive material made of a eutectic composition of 80% by weight of gold and 20% by weight of tin in this embodiment, this example is illustrative and not restrictive. For example the conductive material can be made of a different composition of a gold-tin alloy, a metal such as tin or indium, or a solder such as a tin-lead base solder, a tin base solder, a lead base solder, a gold base solder, an indium base solder, an aluminum base solder or the like.

[0021]
The printing method involves filling the small hole 13 with a copper paste using the screen-printing method. Filling the small hole 13 with a conductive material using the printing method enables the small hole 13 to be effectively and uniformly filled even if the area of the semiconductor substrate 11 or the area of the principal surface of a stacked body on the semiconductor substrate 11 is large. Further, as the conductive material can be filled through to the end of the inside of the small hole 13 the first thin metal film 15 and second thin metal film 16 are electrically connected to the through-hole electrode 17 formed by the conductive material such that the through-hole electrode 17 functions as an electrode.

According to the printing method the small hole 13 may be filled with a copper paste as the conductive material, however the present invention is not limited thereto. Another conductive paste such as a silver paste, a carbon paste, a gold-tin paste and the like may also be used.

[0022]
If necessary, an electrode pad 25 or wiring 26 as shown in FIG. 3 (a) or a metallic bump 27 as shown in FIG. 3 (b) may be formed on one of the principal surfaces A of the semiconductor substrate provided with a through-hole electrode obtained in accordance with this embodiment.

[0023]
Further, the front and rear surfaces of the semiconductor substrate provided with a through-hole electrode according to this embodiment can be electrically connected via the through-hole electrode 17, thus this semiconductor substrate can be used as an interposer when stacking and wiring an electronic device or as a wiring layer when electrically connecting electronic devices together.

[0024]
An embodiment of a method of manufacturing a semiconductor device provided with a through-hole electrode according to the present invention will now be described with reference to FIG. 4 and FIG. 5.

This embodiment describes a method for manufacturing a semiconductor device provided with a through-hole electrode wherein the through-hole electrode can be efficiently formed in a semiconductor substrate provided with a general purpose IC chip for driving and controlling a MEMS (micro electric mechanical system) or a MEMS device such as a sensor or the like.

FIG. 4 depicts this manufacturing method for a semiconductor device provided with a through-hole electrode according to this embodiment in the order of the various processing steps thereof, and is a cross-section view of the semiconductor device cut away along the longitudinal direction of the through-hole electrode. FIG. 5 is a plan view of this semiconductor device provided with a through-hole electrode viewed from above.

[0025]
As illustrated in FIG. 4 (a) the manufacturing method for a semiconductor device provided with a through-hole electrode according to this embodiment involves forming a first silicon oxide film 32 providing an insulating layer of a thickness of 1 μm at least on the location at which a through-hole electrode will be formed, on the surface of the semiconductor substrate 30 on which an electronic device 31 is disposed (first insulating layer formation step). In this embodiment the first silicon oxide film 32 is formed for example by the plasma CVD technique using tetra-ethoxy-silane (TEOS) as the base material.

The method for forming this first silicon oxide film 32 is not restricted to the plasma CVD technique using TEOS. It is also possible to form the first silicon oxide film 32 using the plasma CVD technique with silane (SiH_4). Alternatively, another film formation technique such as a sputtering technique or thermal oxidation or the like can be employed, paying regard to the need to avoid damage to the electronic device 31.

[0026]
In this embodiment a silicon substrate is used as the semiconductor substrate 30 and thus it is possible to easily form the first silicon oxide film 32 of the insulating layer by the plasma CVD technique or the like. Further, if a silicon substrate is used a small hole as described subsequently can be formed with precision in the surface of the semiconductor substrate 30 by deep-reactive ion etching (DRIE).

Moreover, forming the first silicon oxide film 32 provides insulation between a thin metal film formed at a subsequent step and the semiconductor substrate 30. Thus, by patterning this thin metal film in accordance with a desired profile, the thin metal film can be used as a wiring pattern between the through-hole electrode and an electronic device disposed on the semiconductor substrate 30.

Moreover, as the first silicon oxide film 32 is used as an insulating layer, when forming the small hole using DRIE, the first silicon oxide film 32 functions as an etching stop layer, thus the small hole can be formed uniformly in the surface of

the semiconductor substrate 30. Also, it is possible to remove just the first silicon oxide film 32 only, by selecting an appropriate etching gas. In this case, as described subsequently, the thin metal film can serve as an etching stop layer enabling the formation of the desired small hole just below the metal film in a consecutive series of manufacturing steps.

[0027]
Next, as shown in FIG. 4 (b) a first thin metal film 33 and a second thin metal film 34 made of different materials are formed at least over the first silicon oxide film 32 (thin film formation step). In this embodiment, the first thin metal film 33 and the second thin metal film 34 are formed for example by a sputtering technique.

If necessary, it is possible, by patterning these thin metal films by an appropriate method, to form an electrode pad 38 and a wiring pattern 39 for an electronic device 31 as shown in FIG. 5 (a). In this embodiment, as the first thin metal film 33, for example an aluminum silicon thin film is formed while as the second thin metal film 34,an aluminum thin film is formed. The electrode pad 38 and wiring pattern 39 are formed simultaneously.

According to this embodiment an aluminum silicon film is used for the first thin metal film 33 and an aluminum thin film is used for the second thin film 34, however this is not. For example, in order to increase the adhesiveness of the first thin metal film 33 to the through-hole electrode 37 the first thin metal film 33 can be formed by selecting from among gold, platinum, titanium, silver, copper, bismuth, tin, nickel, chromium, and zinc and other suitable metals and alloy thereof, or by combining those material, depending upon the type of conductive material with which the small hole 35 is filled.

Further, in order to improve the adhesiveness of the second thin metal film 34 to a solder bump or circuit pattern (wiring) disposed on another semiconductor substrate, the second thin metal film 34 can be formed by selecting the metallic material from among gold, platinum, titanium, silver, copper, bismuth, tin, nickel, chromium and zinc and alloy thereof, or by combining those meterialdepending upon the type of solder bump or circuit pattern.

Moreover, while the thin metal film formed on the semiconductor substrate 30 is a two layered arrangement comprising a first thin metal film 33 and a second thin metal film 34 in this embodiment, the present invention is not limited by this description and it is possible to form the thin metal film in a multiple layered structure made of three or more layers of different metal.

[0028]
By forming the thin metal film on the semiconductor substrate 30 in a multiple layered structure made of two or more layers of different metals it is possible to improve the adhesiveness of the thin metal film to the conductive material filled inside the small hole as described subsequently, and therefore possible to

achieve reliable electrical connection between the through-hole electrode and the thin metal film (in this case, the first thin metal film 33 and the second thin metal film 34).

If the structure shown in FIG. 4 (b) has been realized by ordinary IC manufacturing processes, this embodiment begins from the process illustrated in FIG. 4 (c).

[0029]
Next, as illustrated in FIG. 4 (c) and FIG. 5 (b), a small hole 35 is formed by a DRIE technique on the semiconductor substrate 30 from the principal side B reaching to the first silicon oxide film 32 in a position on the principal side B, (the surface opposite that on which the electronic device 31 and electrode pad 38 are formed), overlapping that of the electrode pad 38 (small hole formation step).

The form of the cross-section on the plane perpendicular to the depthwise direction of the small hole 35 may have any profile such as a circle, an ellipse, a triangle, a square, a rectangle and so forth, the size thereof being determined in accordance with the size, conductivity (resistance) and the like of the desired semiconductor substrate provided with a through-hole electrode.

[0030]
Using the DRIE technique it is possible to easily perform microscopic machining of the small hole 35, moreover, by using an appropriately selected semiconductor substrate and etching gas, the small hole 35 can be formed and the second silicon oxide film just below the first thin metal film 33 and the second thin metal film 34 can be removed in consecutive processes as described subsequently, thereby enabling the desired small hole 35 to be formed efficiently.

[0031]
Next, as illustrated in FIG. 4 (d) a second silicon oxide film 36 having a thickness of 1 μm or thereabout that functions as an insulating layer is formed on the other principal surface, principal surface B, of the semiconductor substrate and on the inside surface of the small hole 35 (second insulating layer formation step). In this embodiment, this second silicon oxide film 36 is formed for example by the plasma CVD technique with tetra-ethoxy-silane (TEOS).

The method for forming this second silicon oxide film 36 is not restricted to the plasma CVD technique using TEOS. It is also possible to form this film using the plasma CVD technique with silane (SiH_4). Alternatively, another film formation technique such as a sputtering technique or thermal oxidation or the like can be employed, paying regard to the need to avoid damage to the electronic device 31.

[0032]

Next, as illustrated in FIG. 4 (e), the first and second silicon oxide films 32 and 36 are removed by an etching process, only at the end part of that side of the small hole 35 at which the first thin metal film 33 and the second thin metal film 34 are formed, exposing the first thin metal film 33 to the inside of the small hole 35 (insulating layer removal step). An anisotropic etching process may be used for removing only the silicon oxide films 32 and 36 above the small hole 35 while protecting the silicon oxide film on the rear surface of the semiconductor substrate 30 by a resistant material. In this embodiment the first and second silicon oxide films 32 and 36 are etched using the dry etching method by an RIE (reactive ion etching) technique using carbon tetrafluoride (CF_4) as an etching gas.

[0033]
Next, as shown in FIG. 4 (f) a conductive material is filled into the small hole 35 by a molten metal suction method or a printing technique in order to form a through-hole electrode 37 (conductive material filling step) thereby realizing a semiconductor device provided with a through-hole electrode.

This process of filling a conductive material into the small hole 35 at the conductive material filling step electrically connects the first thin metal film 33 and the second thin metal film 34 to the through-hole electrode 37.

[0034]
Here, the molten metal suction method involves using a eutectic composition of 80% by weight of gold and 20% by weight of tin. On the other hand, when a printing technique is used the small hole 35 may be filled with a copper paste by a screen printing technique. If the molten metal suction method is used to fill the small hole 35 with a conductive material, even a microscopically small hole 35 can be filled effectively. Further, as the small hole 35 can be completely filled with the conductive material through to the end part thereof, the first and second thin metal films 33 and 34 are electrically connected to the through-hole electrode 37 formed of this conductive material such that the through-hole electrode 37 functions as an electrode.

Although the small hole 35 may be filled using the molten metal suction method with the conductive material made of a eutectic composition of 80% by weight of gold and 20% by weight of tin in this embodiment, this example is illustrative and not restrictive. For example as the conductive material, a different composition of a gold-tin alloy, a metal such as tin or indium, or a solder such as a tin-lead base solder, a tin base solder, a lead base solder, a gold base solder, an indium base solder, an aluminum base solder or the like can be used.

[0035]
The printing method involves filling the small hole 35 with a copper paste (Cu) using for example the screen printing method. Filling the small hole 35 with a conductive material using the printing method enables the small hole 35 to be

effectively and uniformly filled even if the area of the semiconductor substrate 30 or the area of the principal side of a stacked body on the semiconductor substrate 30 is large. Further, as the conductive material can be filled through to the end of the inside of the small hole 35, the first and second thin metal films 33 and 34 are electrically connected to the through-hole electrode 37 formed by the conductive material such that the through-hole electrode 37 functions as an electrode.

According to the printing method the small hole 35 may be filled with a copper paste as the conductive material, however the present invention is not limited thereto. Another conductive paste such as a silver paste, a carbon paste, a gold-tin paste and the like may also be used.

[0036]
If necessary, an electrode pad 40 or wiring pattern 41 as shown in FIG. 6 (a) or a metallic bump 42 as shown in FIG. 6 (b) may be formed on the other principal surface B of the semiconductor device provided with a through-hole electrode obtained in accordance with this embodiment.

Moreover, in the semiconductor device provided with a through-hole electrode as obtained by this embodiment the front and rear surfaces are electrically connected via the through-hole electrode 35, thereby enabling stacking of devices and reducing the size of elements.

[0037]
Furthermore, in the semiconductor device according to this embodiment the electronic device 31 and the through-hole electrode 37 are electrically connected to each other by patterning the first thin metal film 33 or the second thin metal film 34 to form the electrode pad 38 and wiring pattern 39 at the same time. However, the present invention is not limited thereto. For example, it is possible to connect electronic device 31 to the electrode pad 38 by wire bonding with a metallic wire.

[0038]
[Effects of the Invention]
As explained above, the manufacturing method according to the embodiments as described above enable a through-hole electrode to be efficiently formed through a semiconductor substrate on which an electronic device or devices or a wiring pattern have been fabricated, therefore making it possible to easily manufacture a semiconductor substrate provided with a through-hole electrode or a semiconductor device provided with a through-hole electrode.

[BRIEF DESCRIPTION OF THE DRAWINGS]
[FIG. 1] depicts the manufacturing method for a semiconductor substrate provided with a through-hole electrode according to an embodiment of the present invention in the order of the various processing steps thereof, and is a

cross-sectional view of the semiconductor substrate cut away along the longitudinal direction of the through-hole electrode.

[FIG. 2] is a plan view of that semiconductor substrate provided with a through-hole electrode viewed from above;

[FIG. 3] is a schematic cross-section view showing an example of the structure of a semiconductor substrate provided with a through-hole electrode obtained by the manufacturing method for a semiconductor substrate provided with a through-hole electrode according to the present invention;

[FIG. 4] depicts the manufacturing method for a semiconductor device provided with a through-hole electrode according to an embodiment in the order of the various processing steps thereof, and is a cross-sectional view of the semiconductor device cut away along the longitudinal direction of the through-hole electrode;

[FIG. 5] is a plan view of this semiconductor device provided with a through-hole electrode viewed from above;

[FIG. 6] is a schematic cross-section view showing an example of the structure of a semiconductor device provided with a through-hole electrode obtained by the manufacturing method for a semiconductor device provided with a through-hole electrode according to the present invention;

[FIG. 7] is a schematic cross-section view showing an example of the structure of a semiconductor substrate provided with a through-hole electrode;

[FIG. 8] is an explanatory drawing showing an example of a conventional manufacturing method for a semiconductor substrate provided with a through-hole electrode; and

[FIG. 9] is a schematic cross-section view showing another example of the structure of a semiconductor substrate provided with a through-hole electrode.

[Brief Description of the Reference Symbols]
11, 30... Semiconductor substrate
12, 32... First silicon oxide film
13, 35... Small hole
14, 36... Second silicon oxide film
15, 33... First thin metal film
16, 34... Second thin metal film
17, 37... Through-hole electrode
31... Electronic device

[ABSTRACT[
[Task] To provide a manufacturing method for a semiconductor substrate provided with a through-hole electrode and a manufacturing method for a semiconductor device provided with a through-hole electrode, in which it is possible to effectively form a through-hole electrode in a semiconductor substrate on which a device or a wiring pattern have already been fabricated.
[Solution] This manufacturing method includes forming a first silicon oxide film 12 on a principal surface of a semiconductor substrate 11, forming a small hole 13 through the semiconductor substrate 11 from the principal surface A reaching through to the first silicon oxide film 12 on the principal surface on the other side of the semiconductor substrate 11, forming a first thin metal film 15 and a second thin metal film 16 on the first silicon oxide film 12, removing the first silicon oxide film 12 at the end part of the small hole 13 and filling inside the small hole 13 with a conductive material to form a through-hole electrode 17, thereby realizing the semiconductor substrate provided with a through-hole electrode. The small hole 13 is formed using a DRIE technique. The conductive material may be filled inside the small hole 13 using a molten metal suction method or a screen printing method.

[Elected Drawing] FIG. 1